

## CLAIMS

What is claimed is:

1. A system for coherent beam combination comprising:
  - an unstable resonator;
  - at least two gain media located within said unstable resonator;
  - wherein a first electromagnetic field produced by a first gain medium of said at least two gain media propagates through a portion of a second gain medium of said at least two gain media after one or more roundtrips within said unstable resonator; wherein said first electromagnetic field is in-phase with a second electromagnetic field produced by said second gain medium.
2. The system of Claim 1, further comprising an output beam exiting said unstable resonator.
3. The system of Claim 3, wherein said output beam has an intensity proportional to an amplitude product squared, said amplitude product being an amplitude of said first electromagnetic field multiplied by an amplitude of said second electromagnetic field.
4. The system of Claim 1, wherein said at least two gain media are laser gain media.
5. The system of Claim 1, wherein said at least two gain media are parametric gain media.
6. The system of Claim 1, wherein said separation distance is between about 100 microns to about five millimeters.
7. The system of Claim 1, wherein said separation distance is about 1 millimeter.
8. The system of Claim 1, further comprising a heat-conducting element in contact with said at least two gain media.

9. The system of Claim 8, wherein said heat-conducting element lies in a plane transverse to a longitudinal axis of said unstable resonator.
10. The system of Claim 9, wherein said heat-conducting element contacts portions of said at least two gain media that are parallel to said longitudinal axis.
11. The system of Claim 8, wherein said heat-conducting element is made of diamond or amethyst.
12. The system of Claim 11, wherein said diamond is optical quality diamond.
13. The system of Claim 4, wherein said laser gain media are selected from the group consisting of Nd:YAG, Nd:YLF, Cr:LiSAF, Cr:LiSGAF, Cr:LiCAF, Ce:LiSAF , and Ti:Sapphire.
14. The system of Claim 5, wherein said parametric gain media are quasi-phase-matched (QPM) nonlinear crystals.
15. The system of Claim 5, wherein said parametric gain media are birefringent nonlinear crystals.
16. The system of Claim 14, wherein said parametric gain media are selected from the group consisting of periodically twinned gallium arsenide (PTGaAs), periodically poled lithium niobate (PPLN), periodically poled KTP (PPKTP), periodically poled RTA (PPRTA).
17. The system of Claim 15, wherein said parametric gain media are selected from the group consisting of ADP, BBO, GaSe, CdGa<sub>2</sub>S<sub>4</sub>, CdSe, CdGeAs<sub>2</sub>, LiNbO<sub>3</sub>, LiTaO<sub>3</sub>, LBO, KDP, KTP, AgGaS<sub>2</sub>, AgGaS<sub>2</sub>, and proustite.
18. The system of Claim 1, wherein said at least two gain media comprise four gain media.
19. The system of Claim 18, wherein said four gain media are in a two-by-two array.

20. The system of Claim 1, wherein said unstable resonator is a negative or positive-branch unstable resonator.
21. The system of Claim 1, wherein said unstable resonator is a confocal unstable resonator.
22. The system of Claim 21, wherein said confocal resonator is a confocal-planar or confocal-convex unstable resonator.
23. The system of Claim 1, wherein said unstable resonator is an unstable ring resonator.
24. A method for coherent beam combination comprising the steps of:  
    producing a first electromagnetic field from a first gain medium;  
    producing a second electromagnetic field from a second gain medium;  
    expanding said first and said second electromagnetic fields in an unstable resonator having a magnification factor; and  
    coherently combining said expanded first electromagnetic field with said expanded second electromagnetic field.
25. The method of Claim 24, further comprising producing an output beam with an intensity that is proportional to an amplitude product squared, said amplitude product being an amplitude of said first electromagnetic field multiplied by an amplitude of said second electromagnetic field.
26. The method of Claim 24, wherein said step of producing a first electromagnetic field further comprises producing signal and idler fields.
27. The method of Claim 24, further comprising producing a third electromagnetic field and expanding said third electromagnetic field in said unstable resonator.
28. The method of Claim 27, further comprising coherently combining said expanded third electromagnetic field with said expanded first and said second electromagnetic fields.

29. The method of Claim 24, further comprising removing heat from said first and said second gain media.